Compressed Air

DEVOTED TO THE USEFUL APPLICATION OF COMPRESSED AIR.

VOL. IV. NEW YORK, MAY, 1899. No. 3

MINING COAL BY COMPRESSED AIR MACHINERY.

COMPRESSED AIR TOOLS.

PNEUMATIC MOTOR HOISTS, DRILLS, REAMERS, TAPPERS, CRANE MOTORS, CENTER GRINDERS, ETC., ETC. . . . . .

DRILLS MADE IN FOLLOWING SIZES:

00......	capacity......	$\frac{3}{16}$ in......	weight......	4 lbs.
0......	"	...... $\frac{1}{2}$ in......	"	......$10\frac{1}{2}$ lbs.
0 extra	"	...... $\frac{3}{4}$ in......	"	......15 lbs.
1......	"	...... 1 in......	"	......35 lbs.
1 extra	"	......$1\frac{1}{2}$ in......	"	......49 lbs.

PNEUMATIC MOTOR HOISTS.

HOISTS IN THE FOLLOWING CAPACITIES.

CLASS A. Differential.

1,500, 3,000, 5,000 and 10,000 lbs.
Length of Lift per minute 10 to 13 feet.

CLASS B. Quick Acting Friction Brake.

800, 1,500 and 2,500 lbs.
Length of Lift per minute 28 to 36 feet.

EMPIRE ENGINE & MOTOR CO.,

OFFICE AND WORKS: ORANGEBURGH, N. Y.

CORRESPONDENCE SOLICITED.

Compressed Air.

A MONTHLY PUBLICATION DEVOTED TO THE USEFUL APPLICATION OF COMPRESSED AIR.

W. L. SAUNDERS, - - Editor and Proprietor
A. E. KENNEY, - - - - Managing Editor
J. E. QUINTERO, - - - - - Treasurer

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VOL. IV. MAY, 1899. NO. 3.

In the April number of "Compressed Air" we published an article on "Compressed Air Enterprises," by George C. Densmore, C. E. In it he quotes the views of "M. Edbank, a prominent consulting engineer of Paris, on a short business trip to this country." M. Edbank discussed the subject of air traction freely and emphasized the objections to compressed air for that purpose, and endeavored to expose all that was bad in the system. It was chiefly because the article contained these objections that we published it. Compressed air can now afford these criticisms. The conditions are so advanced that their publication can do no more than to improve the general work in compressed air. A few years ago such an opinion might have been considered a black eye, but as compressed air can be looked upon as having passed the "black eye" period, we believe no harm can come from such expressions. From our point of view it is only incidental to the progress of air power.

An esteemed correspondent, however, takes exception to the interview with M. Edbank and says that it was a "calumny on air" and that he investigated the statements made at the time and wrote to various points in Europe where air was used and found that the statement that people were injured by explosions was false. Our correspondent also discovered that Edbank was not the man's real name, but that he had changed it to that, and that he was representing an electric company with poor results. Be this as it may, it is well known that explosions are not to be dreaded if the past is to be a guide for the future.

With all the air that is used now, it is hard to recall a single accident, explosion or otherwise that has occurred and did fatal damage. This matter is not a factor in the consideration of compressed air.

Another month and the subject of compressed air traction will be before us in a way that it has never appeared in before and M. Edbank having changed his name, if we can rely on our correspondent, will then have an opportunity to change his opinion, which we trust he can do with equal facility.

A Central Power Scheme.

A company is at present in course of formation to be called "The Kalgoorlie Goldfields Electromotive Power Compressed Air and Electric Light Company, Limited." The object of the company is to establish a central power station on a site conveniently situated for the supply of electromotive power, compressed air, and electric light to the group of the larger gold mines on the Kalgoorlie goldfields. The Kalgoorlie miner speaks of the project in this manner.

There is probably no better field in the world for the successful carrying out of such a scheme than the Kalgoorlie goldfields, as the best mines are situated in a compact group, so that the distance of the mine most remote from the central station as suggested in this scheme will not exceed a mile, while the majority of them will be less than half that distance. Within a radius of two miles there are about

fifty leases that are on payable gold, which in the near future will require power, at as cheap a rate as possible.

Mr. Sam Wilson, mechanical and mining engineer, Coolgardie and Kalgoorlie, is the chief promoter of the Kalgoorlie central power scheme. During the last twelve months he has been acquiring information and data respecting the same, not only here but from all parts of the world wherever accumulative power is being used. As the founder, managing director and largest shareholder of the Pioneer Foundry and Engineering Works in this place, Mr. Wilson has had special opportunities of becoming acquainted with nearly all the mine managers and electrical and mechanical engineers on the field, all of whom, without exception, recognize the fact that a large central power company will do more to develop and encourage the mining industry than anything else. Mr. D. C. Smith, electrical engineer of the Kalgoorlie Council, has given valuable assistance to the promoters of the Kalgoorlie central power scheme by his practical and technical knowledge.

It has been ascertained that, with one or two exceptions, there is no mine in the Kalgoorlie district able to produce power for less than from 6s. 6d. to 7s. per i. h. p., per 24 hours, and the average cost is usually higher than this. The proposed company does not intend to charge more than 4s. per i. h. p., thus effecting a saving of at least 25 per cent. Fourteen mines are at present using about 3,600 i. h. p., so that the profit these mines would make by taking their power from the Central Power Company's works would be over £100,000 per 365 days working, still leaving a very handsome profit for the company.

The company proposes to at once erect a plant that will generate 3,000 i. h. p. for compressed air, to work 300 rock drills, and for underground hauling and pumping; 2,000 i. h. p. electromotor power, for winding, crushing, pumping and every other purpose; and 300 h. p. for electric lighting. It is thought that double this power will be required before the plant is completed. The capital of the company is £500,000, and it is proposed to call up £300,000 at once. Some months ago the promoters put this scheme, with all the required data and particulars, into the hands of Mr. William Griffith, the representative of Messrs. Bainbridge, Seymour & Company, the large mining engineers, St. Helen's place, London, who perceived its importance, and he at once forwarded all particulars to London. Through the able assistance given by Mr. Griffith and his firm the scheme has been taken over and registered by a wealthy, influential syndicate in London, the chairman of which is also chairman of one of the largest electric lighting companies in London.

The syndicate has received very great encouragement from the largest mining boards in London, and it is thought that they will subscribe half the required capital, as they will be the most benefited by the company, and thus share half its profits, and secure equal representation on the London and local boards which will control the company. As the power will be registered by meter at the different mines, only what is used will be paid for. Each mine will provide its own receivers for compressed air; the electromotors will be the property of the power company, and a rent will be charged for their use and for keeping them in order.

In order to guarantee continuous power a reserve plant will be kept ready for use in case of a breakdown; accumulators will also be used for storing both compressed air and electricity for several hours, which can be drawn upon when required.

To the non-producing mines, to those which are being developed, and especially to those with small capital, the advantages are incalculable, as such mines will be saved the expense of putting down power and compressor plants, and will only be called upon to pay for the power and compressed air used. This should prove a great inducement to many developing mines that are at present closed. There is very little doubt that before the year is out all the power used about Kalgoorlie for lighting and other purposes will be drawn from the central power.

The scheme and plans are at present before a board of mechanical and mining experts in London, and it is expected that one or two of them will be here in a week or two to consult with the local promoters, and in a few weeks at most the company will be placed on the London market.

It has been ascertained from the local representatives of several of the principal mines that they would be willing to give

their support to such a scheme, and it is proposed in the first instance to put down plant sufficient to supply their requirements, with a fair margin to meet any further demand. The following table gives a list of some of the principal mines, with the approximate power, number of lamps required for lighting, a probable number of compressed air drills either in use now or required in the near future:

It has therefore seemed reasonable to base the accompanying estimates on the following figures:

2,000 actual h. p. delivered on the mines for crushing, pumping, hauling, winding, etc., by means of electromotors.

300 actual h. p. in the form of electric light.

2,000 actual h. p. delivered on the mines in the form of compressed air.

4,300 total actual h. p. delivered.

But as the losses of transformation and transmission in the electric power and light circuits will amount to about 30 per cent., and the losses in air transmission to 50 per cent., the total h. p. generated in the central station will amount to 5,443 h. p., and this figure has been adopted in calculating capital and working expenses.

From these estimates it will be seen that the capital actually required is £235,-500, but as it is anticipated that an early extension of plant will be necessary, it is proposed to have an authorized capital of £500,000 and to call up £300,000 at once, which will leave a sufficient margin for running expenses, while the plant is being filled up, the balance to be held in reserve toward duplicating the power, which more than probable will be necessary at an early date.

The annual running expenses will amount to £117,093, and the gross revenue, by charging 4s. 9d. per actual h. p. delivered, or 3s. 17d. per electric unit, will be £214,747 10s., leaving a profit of £97,654, equal to a **profit** of 32 per **cent.** on £300,000.

To give mine-owners a direct inducement to become consumers, it is proposed to give them the opportunity of subscribing conjointly one-half of the required capital, the other half being offered to the public, and it is further proposed to make the shares held by the mine-owners preferential to the extent of paying 6 per cent. on the capital held by them as a first charge on the profits. The ordinary shareholders will then receive 6 per cent., and the balance of the profits will then be divided evenly among all shareholders. It is also proposed to make a reduction in the price of power to the mines holding capital in the company, 4s. 6d. per h. p. being charged to them as against 5s. to mines holding no capital, and, further, a sliding scale of charges will be introduced wherebv the largest consumer of energy will pay the smallest rate per h. p.

By this arrangement the mine-owning shareholders will get their power: (1) at 30 per cent. of the present cost, (2) will be guaranteed 6 per cent. on the money invested in the company, and (3) will still further reduce the cost of power by receiving the balance of profits in dividends, which collectively will reduce the

	No. of Drills	No. of 16 C. P. Lamps.	H. for other purposes	Total H. P.	For 274 days.		Saving
					Present Cost at 6/6	Cost at 4/9	
Australia	30	200	700	870	£77,473	£56,614	£20,858
Lake View	25	200	240	385	34,284	25,054	9,230
Great Boulder	18	150	240	345	30,722	22,450	8,272
Ivanhoe	15	200	150	245	21,817	15,943	5,874
Golden Horseshoe	15	150	150	240	21,372	15,618	5,754
Kalgurli	12	100	100	170	15,138	11,063	4,075
Kalgurli North	12	100	100	170	15,138	11,063	4,075
Kalgurli South	12	100	100	170	15,138	11,063	4,075
South Boulder	12	50	100	165	14,693	10,737	3,956
Hainault	12	50	100	165	14,693	10,737	3,956
Brookman's Boulder	12	50	100	165	14,693	10,737	3,956
Boulder No. 1	12	50	100	165	14,693	10,737	3,956
Perseverance	12	50	150	215	19,146	13,991	5,155
Oroya	12	50	100	165	14,693	10,737	3,956
Totals	211	1,500	2,430	3,635	£323,693	£236,545	£87,148

cost of power to half the present expense. The ordinary shareholders, on the other hand, will be guaranteed a sufficient number of customers to ensure the success of the undertaking.

For the proper control of the company it is suggested that three mine managers represent the mine-owners' interests, while the other three directors will be appointed by the ordinary shareholders. It is further suggested that no director shall receive any remuneration until a dividend of at least 10 per cent. is declared. The method proposed for carrying out this scheme is to convey the electricity from the generating station at high pressure (2,000 volts) to sub-stations, placed in as close proximity to the various points where power is required as practicable. Those sub-stations will be furnished with accumulators capable of supplying the whole energy called for, for at least an hour. The power will be then taken from the accumulators at a lower and safer pressure to the various motors and lighting circuits.

The advantages of this method of distributing are:

1. The transmission is effected over the principal distances with a comparatively small main, and with small loss of pressure (about 2½ per cent.).

2. By the introduction of accumulators the pressure can be conveniently reduced to a perfectly safe point before being conveyed to the motor.

3. It is possible to keep the lamp at a perfectly steady c. p., notwithstanding the variations in the motor circuits caused by starting and stopping.

4. In the event of a breakdown in the generating machinery, the accumulators would act as a reserve for at least an hour, and so prevent a stoppage at the mines.

5. As the load of power circuits is always of a fluctuating nature, the use of accumulators will enable the engines to work steadily at their most economical point, the fluctuations being taken up and given off by the batteries.

6. That it is perfectly flexible in providing for variations in pressure for all purposes, as any pressure may be obtained from two to 2,000 volts, without any alteration to the existing arrangements, other than changing a wire.

With reference to the compressed air system, it is found to be more economical to compress the air direct at the central station, and convey it by pipes to the various mines, rather than simply to supply power on the mines to drive the various compressors, as thereby the cost of plant would be greater and the losses of transformation heavier; but in order to economize in the outlay of pipes, and also to preserve a uniform pressure at the mines, it is proposed to transmit the air at 300-lb. pressure per square inch to receivers capable of storing energy for 200 drills for an hour, placed at the sub-stations, and then to reduce the pressure before entering the service-pipes to the mines, to the usual working pressure of 80 lbs. by means of reducing valves.

Both the electric and compressed air energy will be measured by meter, so that only the power actually used will be charged for.

It is found in the Eastern colonies that a mine producing 5 dwt. of gold per ton crushed, can be made to pay dividends with care and economy, and while it would be rather rash to predict that the same state of economy would be arrived at here, by a saving in the cost of power, it is at all events safe to say that the introduction of the scheme just detailed would be a step in that direction, and in some cases might make the difference between a dividend-producing and a call-producing mine.

This system has been introduced on the Rand in South Africa by two large companies with great advantage to themselves and to the mines utilizing the energy supplied by them, although the conditions there are not so favorable for economical running as in the Kalgoorlie goldfield, owing to the fact that the mines cover a much larger area, and the expense of labor is very much less.

In America the same method of generating power has been adopted in the large mining centres with most successful results, while such methods also are finding favor in Great Britain and on the Continent, where circumstances allow of a central generating power.

A machinery area has been secured adjoining the present railway (that will be an important consideration), in almost the centre of what is known as the gold-bearing belt, which embraces over fifty distinct companies or leases, nearly all of which have been proved payable mines, but will require power and light. It is therefore almost certain that by the time

the plant is erected the whole of the proposed power and light will be applied for, and in the near future a large extension will be necessary.

There are at present a considerable number of mines that are in a forward state of development and will soon require machinery, and consequently they will be only too pleased to avail themselves of the proposed company's power, etc., if the scheme is carried out without delay.

Should any of the plant now in use by any of the mines which propose to take power from the central station be found suitable, the company would be prepared to take it over at a fair valuation and utilize it in the central station.

Letters expressing approval of and wishing success to the scheme have been received by Mr. Samuel Wilson from Mr. R. Hamilton, Great Boulder; Mr. T. Hewitson, Ivanhoe; Mr. William Dick Golden Horseshoe, and the managers of all the leading mines in this district.

Trial of a New Air Power Car.

The first of the air-power cars for the Twenty-eighth and Twenty-ninth street line of the Metropolitan road made an experimental run over the Twenty-third street line April 16th last. Among the officials who made the trip were H. H. Vreeland, president of the Metropolitan; A. A. McLeod, president of the American Air Power Company, which supplies the air motors; Fred Pierson, chief engineer of the Metropolitan; W. H. Knight, chief engineer of the American Air Power Company; M. G. Starritt, assistant engineer of the Metropolitan, and H. D. Macdonald, of the Metropolitan.

The air for these cars will be compressed by the 400-h. p. compressor which has been in operation at the power house near the foot of West Twenty-third street for some time. The 1,500-h. p. compressor is not completely installed. It is expected that it will be in operation within a few weeks, and then the twenty new cars for the Twenty-eighth and Twenty-ninth street line will be started. The roadbed will not be changed now. New rails will probably be laid after the air-power cars begin their trips.

The new cars have the same general appearance as the standard electric cars used by the Metropolitan road. Some of the experimental cars were run on uptown lines among the electric cars and passengers never noticed the difference. The compressed air bottles are carried under the seats, three on a side. These bottles are made in Germany of a specially prepared nickel steel after a process similar to that used by Krupp in making armor plate for battleships. The first bottles were made to withstand a pressure of 4,000 lbs. to the square inch. This left a margin of safety of only 1,500 lbs. The new bottles can withstand a pressure of 13,000 lbs. to the square inch. The maximum working pressure will be 2,500 lbs., and the normal pressure will be 2,200 lbs.

In the new power house at Eleventh avenue and Twenty-fourth street is the 1,500-h. p. air-compressor, which has much the appearance of a marine engine. This vertical compressor is a great improvement over the horizontal compressor now in use and will do its work much more economically. The compressor is about 60 ft. high and has a fly wheel 22 ft. in diameter. It is a four-stage compressor. The air is taken in at the rate of 64 cu. ft. to a stroke. In the first compressing cylinder it is under a pressure of 50 lbs. to the square inch. In the second compressor the pressure is raised to 172 lbs. and the original bulk is reduced to 18 cu. ft. In the third compressor the pressure is 589 lbs. and the bulk is reduced to 5 cu. ft. Finally, in the last compressor, the pressure is raised to 2,000 pounds and the bulk reduced to 1½ cu. ft. This is all done in four seconds. Compressing air so rapidly heats it to a high degree of temperature, and so after each compression, the air is cooled by passing over cold-water pipes.

The capacity of the new compressor, if the cars were charged directly from it, would be eighty cars. By establishing a reservoir of compressed-air bottles the capacity will be increased indefinitely. From the compressor bottles the car bottles can be charged in two minutes.

A car will run sixteen miles on a single charge, and the cars, as built, will have a speed capacity of from ten to twelve miles an hour. They will be run at from five to six miles an hour and will be charged after every other trip.

The mechanism of the new air motors is very simple. Unlike the first air-power cars, in which there was a great number

of moving parts, the engines now to be used have very few moving parts. The running gear moves in a bath of oil.

The motors are controlled by the motormen just as the motormen control the electric motors now. The platform controllers are only slightly different in appearance from those used on the electric cars.

The new cars run very smoothly. They are started with very little of a jerk. The aim of the Metropolitan's engineers has been, in fact, to produce a car which should be as much like the standard electric car as possible, so that the running of them would not confuse the employees. The car which made the experimental run yesterday was hailed several times by persons who thought it was one of the crosstown electric cars. Over in Paris the air-power cars are built on locomotive designs.

The new cars for the crosstown line will be the first cars to be regularly run on a street railroad in this country.

Economy of Compressed Air Power Transmission.

By Wm. O. Webber.

The recent great interest in compressed air for power transmission suggests that a few figures on the possibilities of this method of storing and converting energy might be pertinent. It has recently been found possible to compress air directly by falling water without the necessity of using water wheels, with the consequent loss in friction of from 15 to 20 per cent., and also the loss in transforming the rotary motion by means of displacement compressors, with the further consequent loss due to the raising of the temperature of the air compressed and the condensation of the water vapor from the air. In fact this last feature has been one of the chief obstacles to the use of compressed air.

It is a well-known fact that water vapor contained in air may be condensed by falling temperature and also by an increase in pressure. The atmosphere holds varying amounts of water vapor, depending almost wholly upon its temperature. At 75 deg. Fahr. 1 cu. ft. of air can hold 10 grains of water vapor. Under average conditions it would hold 7 or 8 grains. Suppose 1 cu. ft. of air to be compressed from atmospheric pressure—that is 14.7 lbs. per square inch—to 100 lbs. gage pressure. The volume of the air and vapor will be reduced to about one-eighth. The effect of the rise of temperature upon the vapor contained in the air when no cooling device is used, exceeds the effect of the increase in pressure, and no condensation of the contained vapor takes place during compression; but the air must, during transmission, lose heat and return to about the same temperature as before compression, consequently from three-fourths to seven eighths of the vapor will be condensed, because 1 cu. ft. at the higher temperature holds eight times as much vapor as 1 cu. ft. of the atmosphere. Hence the water will constantly collect in the air mains, and in cold weather will freeze and obstruct the passage of the air.

In short transmission the air may not suffer a great fall in temperature, and may carry the larger portion of the vapor with it; but the sudden and considerable fall in temperature caused by the air expanding against the resistance of the pistons is sufficient, not only to condense, but also to freeze the moisture in the cylinder and exhaust ports of the engine. This is a continual source of trouble in many instances where air has been compressed by cylinder compressors. An attempt is made, with only partial success, to overcome this difficulty by having a large receiver where the air may cool down and deposit its moisture, after compression and before it is used. The above device, however, will not in most cases free the air of moisture sufficiently to insure absence of freezing in engines when there is no reheating.

In compressing air directly by falling water, the bubble of air while passing down the compressor pipe is kept cool by a body of water surrounding it. The time of compression is comparatively slight, being from fifteen to twenty seconds. The bubble of air is compressed at a constant terminal pressure, being that due to the depth of the water, and the excess of water caused by the gradual increase of pressure is deposited on the walls of the bubble. A test made of air hydraulically compressed to 52 lbs. gage pressure showed that it only contained one-fifth of the vapor usually contained in atmospheric air during fine weather, or 14 per cent. of saturation.

If air at 35 deg. Fahr. is heated under a constant pressure, its volume will be increased one four hundred and ninety-fifth for each degree over 35 degs. Air at a temperature of 70 deg. Fahr., if heated to a temperature of 340 deg. Fahr., will increase in volume 50.94 per cent. If, when so heated, this air is thoroughly saturated with moisture by being passed through a tank of water at about the same temperature, each 50 cu. ft. of free air is found to absorb about 1 lb. of water in the form of steam; hence the steam adds more than 50 per cent. to the volume of air. Thus the expansion by saturating with steam and reheating increases the volume more than 100 per cent., or, in other words, doubles the amount of work that any original quantity of compressed air will do. The cost of the reheating is trifling.

The coal required to reheat and secure double efficiency is less than one-eighth of the coal required to do the same amount of compressing with a cylinder compressor, or, reconverting this back into efficiency of work done, it is safe to say that the cost of reheating would represent 8 per cent. of efficiency.

To note what this all means, taking the figures obtained from the tests made in Paris in compressed air transmission, the results to be obtained by compressed air are as follows:

Percentages of Efficiency.

Air compressor	75
Pipe line	98
Reheating and saturating which equals the addition of	100
Then the use of air motors which will give	81
Would give a total of	119

But as the cost of this reheating equals a net result of 87 per cent., the actual net economy is about 103 per cent. This economy of course is limited to conditions in which the cost of pipe for distributing the compressed air and the reheating apparatus would not eat up all the profit. It would then be preferable to compress the air at 75 per cent. efficiency, reheating and moistening it, which would add 100 per cent., convert this air directly into rotary motion by the air motors giving 78 per cent., then through step-up transformers at 96 per cent., wire line at 95 per cent. and step-down transformers at 96 per cent., giving 96 per cent. of the original power, or, taking the loss of heating into effect, 90 per cent. of the original power instead of a net efficiency of about 60 per cent. to 65 per cent. if the same amount of water was used in water wheels and converted directly into electricity and transmitted.

I have gone into some pretty careful figures recently regarding the cost of development under these different conditions, assuming the quantity of water to equal 5,000 h. p., to be transmitted four miles, and have figured out that by water wheels and electrical transmission we would obtain a net of 3,000 h. p. at the end of the line, at a cost of installation of $46 per h. p. The cost of compressing the air, reheating it, and then converting it into electricity and sending it over a wire comes to about forty-three dollars ($43) per h. p., and I believe it would be possible, with a water power situated not more than two miles from the edge of a town, to transmit the compressed air to that point by pipe, and then convert and distribute the power and light by electricity for forty dollars ($40) per h. p.

In a recent publication I saw a reference made to the utilization of the water at the Iron Gates of the Danube, and it struck me at once that it would be a feasible proposition to use this power in the form of compressed air for the purpose of propelling the boats up the river and through the canals which are to be constructed, thus making the power of the falling water passing down through that famous gorge, do the work of propelling the boats up against its own current. This of course seems somewhat impractical, but upon careful thought I do not see that it is any more so than water pumping itself up hill, as it certainly does in a hydraulic ram.

Pneumatic Equipment for Boiler Shops.

It is not enough that a modern boiler shop should be equipped with a power punch, shears and rolls, which have until recently seemed to constitute enough of an equipment to satisfy the ordinary boiler builder that he is doing justice to his business, his customers and to himself. While these machines are labor savers of the first order, the proportion of work which they contribute in the man-

ufacture of a boiler is small in comparison to the balance.

To overlook any opportunity to cheapen the production of standard commodities is a positive step towards a business failure, and a number of apparently insignificant savings amount to perhaps just enough to keep the business afloat.

To depend upon the sentiment of the consumer for a higher priced home product is folly, for when the home consumer recognizes the fact that the local manufacturer does not take advantage of recent appliances for cheapening the cost of production, he does them an injustice which they repay by trading elsewhere.

In return for the patronage of a community a manufacturer, in order to establish himself on firm ground, must never permit his patrons to pay out their money for the loss of time entailed by the use of antiquated or inadequate tools or machines.

The pneumatic chipping, calking and light riveting tools, probably broke the ice as it were of the old methods, and took boiler making methods out of the realm of main strength and awkwardness and placed it alongside of machine shop practice. Plate steel may now be machined into boilers as legitimately as cast steel may be machined into engines. The pneumatic hammers have been a great help to boiler makers. In actual test, an operator with the pneumatic hammer cut off a 2½-in. tube in 36 seconds as against 2½ minutes by hand, and 46 tubes were cut off, turned over and beaded with the same tool, in an hour and three-quarters as against five hours doing the same work in the ordinary manner.

Horizontal boiler seams may be calked and trimmed in one-third of the time required by hand labor, and another great advantage is, that in using the pneumatic tool the quality of the blow is the same, consequently the calking should be perfect; whereas in hand calking, unless done by a very skilled mechanic, the quality of the blows varies considerably. The calking is therefore not homogeneous, the heavier blows tending to reduce the effectiveness of the calking done in a lighter manner.

For re-calking an old boiler or recalking seams that have been imperfectly done, the pneumatic hammer is a most advantageous tool. A fresh cut can be made on the sheet in a very short time and in a perfect manner, and the boiler be re-calked with the tool so as to leave the seam in as good shape as if it had been recently manufactured.

It is only necessary to watch the operation of one of these tools in chipping cast iron in cutting off heavy angles and beams or plates in awkward places and positions, to realize what a labor-saving device it is. There are many places where chipping and calking have to be done where it is almost impossible to swing a hammer or to properly guide a chisel or calking tool. Here is where the pneumatic tool shows to its greatest advantage. It weighs but a few pounds and does not occupy a space more than 12 ins. long, and any place into which the arm can be thrust this tool can be pushed and good work be performed.

These tools are especially valuable in light riveting. Not only do they save a great deal of time in ordinary open riveting but in riveting up pipe they prove themselves money makers on every occasion. It is an expensive proposition to lay pipe and rivet up the joints in the ordinary manner. Holes have to be provided for passing into the pipe the hot rivets, which have to be pushed up through the holes and the men have to hold against the riveting from the outside. During all this operation light rivets are becoming cold and the difficulty and annoyance and hard work during the whole task make it expensive and the results inferior to riveting under ordinary conditions. With the pneumatic tool the rivets can be pushed in from the outside; the workmen on the inside of the pipe using the pneumatic tool to rivet it up on the inside. The holding is done on the outside. The workman inside is furnished with good air to breathe and merely has to handle the light tool. No expensive digging out under the pipe has to be undertaken in order to rivet the seams next the ground. In short, it is entirely probable that riveting in this manner can be done for at least one-third the cost and in a very much better manner than by hand.

The riveting up of gasometer rivets, stand pipes and tanks, which are set up outside, can be done much better and in a great deal less time by the use of these labor-saving devices.

These pneumatic hammers are not the only pneumatic tools which are used in modern boiler shops. There are many other appliances; for instance, pneumatic drill and tap combined, for drilling and tapping out the numerous holes required to be made for the stay bolts of fire boxes.

There is also the pneumatic drill, for drilling holes using ordinary twist drills. These machines are extremely easy to handle and they do good work.

There are pneumatic machines also for expanding tubes into place.

Every good boiler shop should also have, in addition to a large pneumatic crane, small pneumatic lifts for handling heads and sheets and pieces of boilers so they can be rapidly placed in position and without the pulling and hauling which would be necessitated by hand labor. A pneumatic crane properly installed in a boiler shop is a valuable acquisition and should be made powerful enough to pick up an ordinary boiler and move it from place to place as required, or for final transportation. The entire surface of the shop in this manner would be made to yield working space, while with no means of lifting and transporting boilers over each other a large portion of the ordinary shop space has to be left open for gang way, and the annoyance and inconvenience of pushing boilers past each other for exit, and the moving of work and tools which are frequently in the way, causes a loss of time and annoyance which amounts to considerable.

In the testing of boilers much time and expense could be saved by having a water tank on the shop floor or in any convenient place, at sufficient height to readily fill any of the boilers for testing. After testing, the water may be expelled from the boiler by compressed air, which will shoot the water back into the tank in a very small fraction of the time necessary to empty a boiler under ordinary circumstances; in fact, emptying a boiler after testing is one of the slow jobs and generally loses a day in shipment, whereas, with the use of compressed air, after a boiler has been tested it can be emptied and shipped inside of an hour. The water is also saved, which in many localities is a considerable item.

Besides the pneumatic tools, a well equipped boiler shop should have a gang shell driller, for drilling holes in the shell, as required for government boilers, and if the shop is of any considerable size, a head spinning machine and furnace would pay for itself in a short time. The ease and rapidity with which ordinary boiler heads can be spun into shape and the certainty of turning out a first-class job, and the economy with which it can be done, should make it a desirable adjunct for any first-class boiler shop. All reasonable sized scraps about the shop can be heated in the same furnace, and with the addition to the plant of two or three forms of inexpensive hydraulic presses, these scraps could be made into manhole crow feet, manhole plates themselves, compressed steel or iron flanges, eyes, angle plates and many other pieces which go to furnish up a first-class boiler, which in cheap work are generally made out of cast iron. All this work, which consists of scarcely more than operating a lever connected to a machine and putting the heated raw material in place, can be done by boys as well as by the most experienced men.

For a large boiler shop the equipment would be incomplete without proper pneumatic or hydraulic riveters for heavy work, and finally when boilers are finished they can be painted more effectively and in one-third the usual time by the use of pneumatic spray painting machines which are now in use amongst most of the large car shops in America.

A compressed air plant to do all this work for an ordinary shop would be a very small one. A 15-h. p. engine, driving a small compressor, could, with sufficient receiver capacity, handle all the business of an ordinary shop, unless the boiler testing was done with compressed air, which, by the way, is, to the mind of the writer, a better method than cold water, for with the use of soap, water and a brush to paint the seams, the smallest leak can be instantly detected by the bubbles blown, and the rapidity with which the pressure can be introduced and released and the absence of water and leakage, makes the whole operation more desirable.

A valuable addition of any boiler shop would be a portable pneumatic plant with the proper tools for doing work away from the shop, such as erecting gasometers, stand pipes, putting in riveted water mains and doing any sheet iron work where the use of these tools saves

in both expense and time. These plants could be small and easily portable and would certainly pay handsomely to the shop that possessed them.

The writer is glad to note that most of our principal shops here in San Francisco have, during the last twelve months, been gradually improving their equipments and installing many of the tools described above, with the most satisfactory results. Never has the output of boilers been so great in San Francisco as during the past six or eight months. While our manufacturers here are handicapped by a limited field and therefore not enjoying the advantages of manufacturing considerable numbers at a time, still the differences between the freight on raw material and the finished product in this community, acts as a protective tariff which partially does away with the disadvantage above mentioned and our boiler makers feel that with modern tools and methods they can hold their own in the competition which is everywhere the life of trade.—E. A. Rix, in The Boiler Maker.

Liquid Air as a New Source of Power. Another Engineering Fallacy.

By President Henry Morton, Ph.D., LL.D., Sc.D.*

During 1894–5 the present writer prepared two articles under the title of "Engineering Fallacies" which were published in this Journal, Vol. XI, pp. 273–294, and Vol. XII, p. 125.

Since that time, though several new forms of what might be termed in a general way "Perpetual Motion Schemes" have appeared, none of them has seemed of sufficient importance to warrant any special notice, but in the March number of *McClure's Magazine* there is published an article entitled "Liquid Air—a new substance that promises to do the work of coal and ice and gunpowder, at next to no cost," which is so eminently calculated to mislead the general reader and even to become the basis of financial frauds, like that of the Keely motor, that it would seem a duty to draw attention to the fundamental errors in scientific principles and in statement of facts which this article contains.

This *McClure* article may be fairly considered as made up of two prominent elements or parts, one of which is the statement of certain things as facts which, as I shall presently show, cannot possibly exist and are inconsistent with other facts stated in the same article and known from other sources to exist as so stated; while the other main element consists of rather vague statements concerning general principles which, though in a general sense true, yet as here used are calculated to cover up or befog the too obvious inconsistencies of the statements of facts, with the established principles of science.

As an example of the first element, we find on p. 400 as follows: "I have actually made about ten gallons of liquid air in my liquifier by the use of three gallons in my engine." This I shall presently show is simply impossible and inconsistent with data given elsewhere in this article and known to be substantially correct.

A sample of the other element is found on p. 399 in the following: "That is perpetual motion you object. 'No,' says Mr. Tripler sharply; 'no perpetual motion about it. The heat of the atmosphere is boiling the liquid air in my engine and producing power exactly as the heat of coal boils water and drives off steam. I simply use another form of heat. I get my power from the heat of the sun; so does every other producer of power.'"

This, while true as a general statement of what might be done on an impractical scale, is not correct as here used to imply that in his experiments Mr. Tripler actually derives or can derive any adequate amount of energy from the heat of the atmosphere or in that sense directly from the sun. This I shall show later, but will first take up the statement that three gallons of liquid air have supplied or can supply the power to liquify ten gallons.

On pp. 402 and 403 of the *McClure* article we are told that Mr. Tripler uses to make his liquid air a steam engine of 50 horse-power and that with this he can make liquid air at the rate of 50 gallons a day. This I know from other sources is substantially correct, and means that *each horse-power in a day (say* 10 *hours) makes one gallon of liquid air.* In other words, one gallon for 10 horse-power hours.

It is again stated in this article on p. 405 that a cubic foot of liquid air contains 800 cubic feet of air at ordinary atmospheric

* *Stevens' Indicator.*

temperature and pressure, or in other words, any volume of liquid air if adequately heated, will expand 800 times in reaching atmospheric temperature and pressure. This also is substantially correct. We may remark in passing that this is nothing wonderful for water when expanded into steam at atmospheric pressure increases about 1700 times in volume, or more than twice as much as liquid air. If we apply to the above data the well known and universally accepted formula for the maximum work done by air when expanded at constant temperature,

$$W = p_2 \, v_2 \text{ hyp log } \frac{v_2}{v_1}$$

We find that a pound of liquid air in expanding 800 times would develop about 190,000 foot-pounds of work. As a gallon of liquid air weighs about 8 pounds this would give eight times as many foot-pounds or 1,520,000. If this work were accomplished in an hour it would represent almost exactly ¾ of a horse-power, because one horse-power means 1,980,000 foot-pounds of work per hour, and 1,520,000 is only a trifle over ¾ of this. From the above it follows as a matter of *absolute certainty* that the maximum power which liquid air could develop in an *ideally perfect engine* without any loss from friction or other cause would be *¾ of a horse-power for an hour for each gallon of liquid air expended.*

We have seen, however, that with his 50 horse-power plant, which on account of its size should operate with considerable efficiency, Mr. Tripler *makes only one gallon* of liquid air with 10 *horse-power-hours.* In other words, he requires to make a gallon of liquid air 12 *times as much power* as a gallon of liquid air could *possibly develop* in an *ideally perfect* engine.

In face of this how supremely absurd is the statement that with a little engine such as the pictures and descriptions in the *McClure* article show, lacking all conditions for efficient working, Mr. Tripler can make 10 gallons of liquid air by the use of three.

Turning next to the statement about using the heat of the atmosphere to develop mechanical energy or work, let us put this to the test of a quantitative example.

Assume the temperature of Mr. Tripler's laboratory to be 70° F. and that he has an abundant supply of water at 50° F. These will be of necessity the limits of work he can get out of the atmosphere, because any lower temperature is only secured by doing work and so expending energy which will be at least equal to the power obtainable from the use of such lower temperature. All the work that can be obtained *for nothing* is that which nature will freely give in the warm air and cool water, supposing both to be supplied freely without charge.

The 20° F. which we may assume as being possibly taken out of the air by the cool water will represent the maximum gift of nature in this shape of "power costing nothing." Now 42 British thermal units, or pounds of water changed 1° F. per minute, will represent one horse-power and as the specific heat of air is about ¼ that of water we would need four times as many pounds of air to produce the same effect. This would call for 168 pounds of air changed 1° F. If, however, the air is changed 10° F. in place of 1° F. we need but $\frac{1}{20}$ or 8.4 pounds of air parting with 20° F. each minute, to give us one horse-power at 70° F. For "round numbers" let us say 8 pounds. Now a pound of air has a volume of about 13.3 cubic feet. Call this also "for round numbers" 13 cubic feet, then 8 pounds of air would be about 104 cubic feet, and this volume of air would have to part with its 20° F. heat each minute to the apparatus, in order to develop *one* horse-power. For a 50 horse-power engine 50 times as much air would be required, or 5200 cubic feet each minute; this would be the contents of a room 26 × 20 feet on the floor and 10 feet high which would have to be drawn through the apparatus each minute in such a way as to completely yield its 20° F. between 70° F. and 50° F. What sort of a boiler or heat-absorbing apparatus can we imagine which would absorb from air, at 70° F., 20° F. of its temperature while the said air was passing through it at the rate of 5200 cubic feet a minute? It would surely need to be "as big as a house" to use a familiar phrase.

This also, be it remembered, makes no allowance for loss by friction, eddy currents, and the like which would be enormous, nor for the power to put this air in motion.

Obviously such a machine would be simply huge in size, and indeed the friction

involved in it would probably use up a large part of the power it could develop.

Suppose, however, that it could be built and operated in place of Mr. Tripler's 50 horse-power steam plant. Its entire output would be 50 gallons of liquid air a day, and this as we have seen, could only develop in an ideally perfect engine ¾ horse-power for an hour for each gallon or 3¾ *horse-power for a day of ten hours.* This does not look as if heat obtained from the atmosphere and operating an engine by aid of liquid air, was likely to become a dangerous rival to the coal mine.

On p. 402 of the *McClure* article it is stated that Mr. Tripler makes his liquid air at a cost of 20 cents a gallon.

We have shown above that the maximum power obtainable from this liquid air, by heating it to ordinary atmospheric temperature, is ¾ of a horse-power-hour. This at 20 cents would be vastly more expensive than power derived from an ordinary steam engine, whose cost ranges from less than 1 cent per horse-power-hour under the best conditions to 3 or 4 cents, where a profit is included, or the conditions are less favorable.

The really difficult thing to explain in connection with this *McClure* article on Mr. Tripler and his liquid air, is how those concerned in its publication (being as I do not doubt honest men) can be deceived or have so deceived themselves as to make and repeat such obviously impossible statements. In this connection, however, I will make a suggestion founded on experience.

Some years ago I was called upon to examine an engine operated with liquid carbonic acid, which was said to have ten times the efficiency of an ordinary steam engine.

I, of course, told the applicant that such a thing was physically impossible and did not deserve investigation, but finding that a number of substantial people had been so impressed by what had been shown them that they would not be satisfied without an investigation, I consented to make one. This proved an easy piece of work. I found that the promoters and others were under the impression that a horse-power was measured by the raising of 33,000 pounds one foot high *irrespective of time*, and in their demonstrations were contented with showing that their engine did this amount of work in *ten minutes.* As, however, a horse-power involves the raising 33,000 pounds one foot high in *one* minute, it was obvious that the power shown by the carbonic acid engine, was $\frac{1}{10}$ of a horse-power and not *one* horse-power, as those exhibiting the engine claimed. This, of course, explained the situation. An engine developing $\frac{1}{10}$ of a horse-power might easily require only $\frac{1}{10}$ as much fuel as an ordinary steam engine developing 1 horse-power, without violating any of the established laws bearing on this subject. The curious thing was that such people as were concerned in this matter, should have been misled on such a simple and elementary subject; but if they were, as I personally know, so misled, why may not Mr. Tripler and his friends be in a similar case?

I could give from my own personal experience many like examples, but have said enough for the present, to make it evident that what is claimed in this *McClure* article for liquid air as a new source of "power which costs nothing," is not founded on fact, but is probably the result of some oversight in observation or calculation not inconsistent with honesty of intention.

On the Liquefaction of Air by Dynamical Action.

BY PROF. J. E. DENTON, M. E., '75 *

It is now known, through the labors of several European physicists, that air as it exists in the earth's atmosphere is a superheated vapor of a liquid, whose boiling point under atmospheric pressure is 312 degrees below the Fahrenheit zero of temperature.

Thus if Ao (Fig. 1) represents the cubic feet occupied by a pound of liquid air at atmospheric pressure, in order to put the substance in the condition of natural air at, say, 60 degrees Fahr., the liquid must be conceived to be evaporated as a saturated vapor until it occupies the volume Ag, at the constant temperature of —312 degrees, and to then be further expanded to the volume AD by superheating the vapor to 60 degrees. To generate the vapor, or to produce the increase of volume Og, would require heat to be supplied equal to the "latent heat" of evaporation, which rough experiment shows to be about 160 British thermal units. To produce the increase of volume gD would require an amount of

**Stevens' Indicator.*

heat equal to 0.238 [60 —) — 312)] = 89 British thermal units, if the mean specific heat of the air over a range of temperature so low was the same as for its natural conditions. The mean specific heat may be greater than 0.238, so that 89 units may be less than the heat necessary to affect the superheating effect.

If the pound of liquid air is put under a pressure of 10 atmospheres, and then heated, it will not begin to vaporize until some higher temperature than —312 degrees is created, as, say, — 275 degrees. This may be conceived to increase the volume of the liquid, as in the case of other substances. Then if the liquid was all vaporized its volume would be increased by $o_1 g_1$, and the latent heat to affect this would be less than that for atmospheric pressure vaporization in the proportion of $o_1 g_1$ to $o\ g$. As the pressure under which the vaporization occurs increases, the liquid volume becomes greater, and the vapor volume less, so that finally there is no difference between them. We do not know the relation of the temperatures and volumes of the vapor and liquid below 39 atmospheres, but physical investigation has determined that the vapor and liquid volumes become identical at 39 atmospheres, and that the temperature is then — 220 degrees.

At this temperature air must occupy the volume at *e* if its pressure is 39 atmospheres or greater, and it may then be considered to exist either as a gas or a liquid. The slightest addition of heat will make it a superheated vapor, and the slightest abstraction of heat will make it a liquid. This temperature is therefore called the "critical temperature" of the substance.

If, therefore, natural air is compressed from the volume *AD* to, say, 150 atmospheres, and then stored in a reservoir at 60 degrees, so that its volume will be *BC*, and if then the pressure is maintained constant,

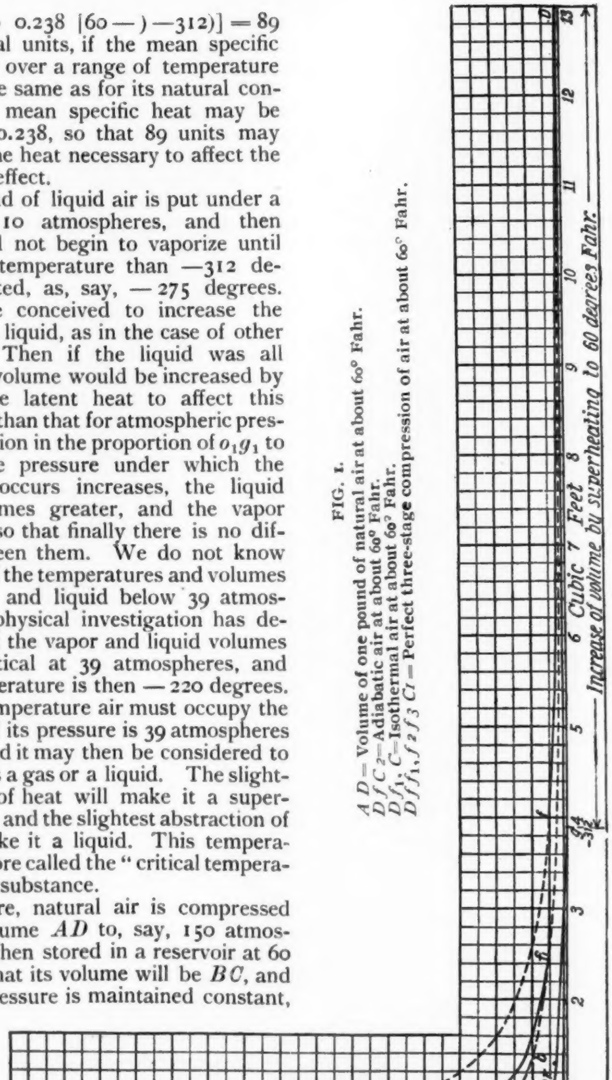


FIG. 1.

$A\ D$ = Volume of one pound of natural air at about 60° Fahr.
$D\ f\ C_2$ = Adiabatic air at about 60° Fahr.
$D\ f_1,\ C$ = Isothermal air at about 60° Fahr.
$D\ f\ f_1,\ f_2\ f_3\ C_1$ = Perfect three-stage compression of air at about 60° Fahr.

FIG. 1.

and sufficient heat is abstracted to more than cool the air to —220 degrees, it will pass into the liquid condition.

Experiments by Mr. C. E. Tripler in New York, and Dr. Linde in Munich, have shown that the necessary abstraction of heat to cool highly compressed air from ordinary temperatures to its critical point or possibly lower, can be accomplished by the dynamical effect resulting from the flow of air through a small orifice connecting a reservoir at high pressure with one at a much lower pressure.

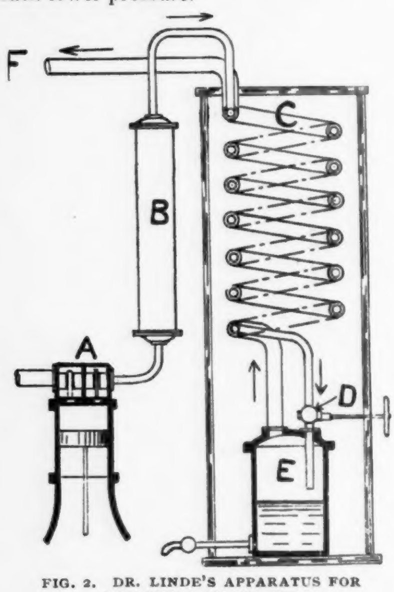


FIG. 2. DR. LINDE'S APPARATUS FOR OBTAINING LIQUID AIR.

Dr. Linde,* and his collaborator, Prof. Schroeter,† of Munich, have published sufficient details of their work to enable the results to be scientifically studied. Linde's apparatus is outlined in Fig. 2. A compressor *A* delivers air from the atmosphere to a reservoir *B*, where it is cooled to ordinary atmospheric temperature. The air also fills the inner of the two coils *C*, and is maintained at a constant pressure therein, while flow occurs through a throttling cock *D* to the chamber *E*, which is maintained at a lower pressure by allowing the expanded air to escape through the outer of the coils *C*. In an experiment in which the higher and lower pressures were 220 atmospheres and 1 atmosphere, respectively, the temperatures were distributed as shown in Fig. 3. Curve No. 1 shows the temperature of the air leaving *B*. Curves No. 2 and No. 3 show its temperature at the high and low sides of the throttle *D*, respectively, and No. 4 shows the temperature of the gas leaving the apparatus at *F*. Liquefaction commenced at about the fifth hour of operation.

It is evident from the curves of Fig. 3 that the flow of the air through the expansion cock causes a permanent cooling of the air greater than the radiation and friction losses of the apparatus, and that this cooling effect being applied to reduce the temperature of the air flowing to the throttling cock continually *increases* the permanent fall of temperature due to the flow through the cock. The second column in Table I shows the cooling effect due to the flow in Linde's experiment.

TABLE I.

Temperature approaching cock. Degrees Fahrenheit.	Fall of temperature by flow through cock. Degrees Fahrenheit.	
	Experiment.	$\delta = 0.5\,(p_1 - p_2)\left(\frac{461}{\tau_1}\right)^2$
+ 30.	35	97
0	65	110
— 30	80	125
— 60	96	132
— 100	112	179
— 150 { Liquefaction commenced.	135	240

The proportions of the coil *C* show that the air escaped with a velocity of about 40 feet per second, which is neglectable in its influence upon the temperature of the air after expansion. The permanent cooling effect is, therefore, attributable to the imperfectly gaseous nature of air, which causes some of the fall of temperature due to the adiabatic expansion governing the flow, to be absorbed in internal work. This cannot be reconverted into temperature like the external work of the expansion, when the velocity of the gas subsides. The possibility of permanent cooling due to the imperfect gaseous nature of air, for flow

* *London Engineer, 1896.*

† *Zeitschrift des Vereines deutscher Ingenieure*, Vol. XXXIX.

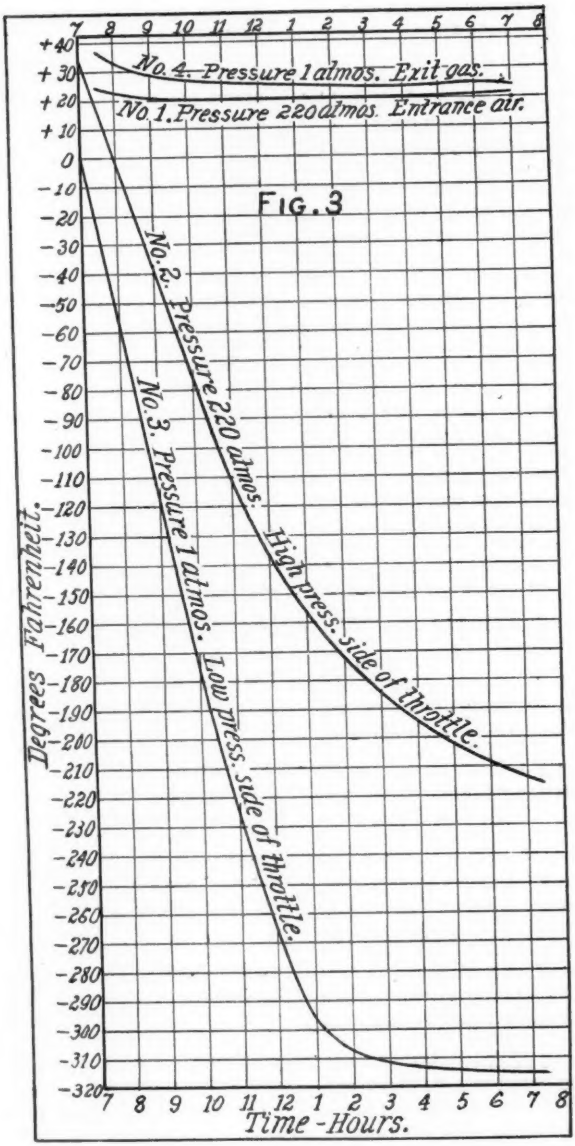


FIG. 3. DISTRIBUTION OF TEMPERATURES.

through a throttling cock, was shown by Thomson and Joule, in 1854. They gave as its measure in degrees Fahrenheit:

$$\delta=0.5\ (p_1-p_2)\left(\frac{461}{\tau 1}\right)^2$$

p_1 and p_2 are given in atmospheres.

τ_1 = absolute temperature of air at high pressure side of the expansion cock.

This formula is the empirical expression of experiments in which p_1-p_2 did not exceed seven atmospheres, and τ_1 was not less than the equivalent of 32 degrees Fahr. The amount of permanent cooling which it would give for the Linde experiment is shown in the third column of Table I. The formula can hardly be expected to hold true quantitatively for such abnormal pressures and temperatures as are concerned with the liquefaction of air, but it suffices to account for the existence of a tangible amount of permanent cooling effect due to the flow of the air through the throttling cock in Linde's apparatus, and for the increase in this cooling effect as the temperature of the air at the high side of the throttle was reduced. It appears that the actual cooling effect as the temperature approached the critical point was about 55 per cent. of the value of δ given by the original formula. This would make $\delta=0.27\ (p_1-p_2)\left(\frac{461}{\tau 1}\right)^2$.

The continuous operation of the apparatus finally results in cooling the air at the high side of the cock to some temperature t_1 which is, say, above the critical temperature t_c when liquefaction commences. Then if the substance remained homogeneous the process of liquefaction might be as follows:

Adiabatic cooling by the flow through the cock reduces the temperature to the critical point, without reducing the pressure to the critical point, and all the air is liquefied. Then as the pressure continues to fall in the jet the temperature of the liquid follows saturated vapor laws, and consequently the release of heat from the liquid causes vaporization, and since at the critical temperature the heat of the liquid is equal to the total heat of vaporization, and the latter may be supposed to increase slightly with pressure —the whole of the liquid will be vaporized to the saturated condition of the lower pressure, and then superheated to the amount of the difference between the total heat of evaporation for the critical temperature and the lower pressure, respectively. There will also be some superheating effect due to the actual energy of the initial adiabatic flow before the air is reduced to its critical temperature.

Now if the cooling effect δ, due to the flow, acts, and is more than sufficient to annul the superheating effect, some of the superheated vapor will be liquefied, and the resulting mixture will be at —312 degrees, the boiling point for atmospheric pressure. This mixture can now act on the air above the throttling cock, and cool it to the critical temperature, thus liquefying it before it flows through the cock. Then the release of heat from the liquid will vaporize and superheat as before, but the δ cooling effect will possibly condense a greater proportion of the air to liquid, as the lower temperature at the high pressure side of the throttle may have increased δ.

By the continued action of these conditions liquid can either be drawn off from the chamber E, or made to liquefy other air confined in a separate vessel lodged in E, or located in the midst of the coils C so as to share with them the effect of the return current from E. The separate liquefying vessel may theoretically be at any pressure, and the liquid in it be cooled so nearly to —312 degrees that it can be collected in a receptacle under atmospheric pressure without practical loss from vaporization. Theoretically, also, the temperature t_1 at the high side of the throttling cock might be reduced so far below the critical temperature by the return action of the mixture of vapor and liquid from E, that the evaporative action from the release of heat from the liquid in flowing through the throttling cock would be exactly neutralized by the cooling effect δ. All of the air would then arrive in E as a liquid, but the portion of this which could be withdrawn, or used to liquefy other air, would be due to the cooling effect δ, the remaining portion being re-evaporated in the return action to effect the cooling of the liquid above the throttle below the critical temperature t_c. In the German experiments the temperature above the throttling cock appears to have not been reduced below t_c.

The amount of liquid permanently producible being dependent upon the cooling effect δ, the algebraic expression of thermal relations according to above hypothesis would be as follows:

Assuming steady liquefaction to be attained,

t_o = temperature of air entering apparatus.

t_1 = temperature of air on high pressure side of throttle.

t_c = critical temperature.

t_2 = temperature of air on low pressure side of throttle.

p_1 = high pressure, atmospheres.

p_2 = low pressure, atmospheres.

r_3 = latent heat of liquid air at p_2. B. T. U. per lb.

λ_1 = total heat of liquid air at p_1. B. T. U. per lb.

λ_2 = total heat of liquid air at p_2. B. T. U. per lb.

a = Superheating due velocity of flow before t_1 becomes reduced to t_c. B. T. U. per lb.

R = losses by radiation, friction and escape of air at less than t_o. B. T. U. per hour.

W = weight of air compressed per hour.

w = weight of air liquefied per hour.

C_1 = specific heat of air between t_o and t_1.

C_2 = specific heat of air between t_1 and t_c.

C_3 = specific heat of air between t_1 and t_2.

Then the whole cooling effect available is $WC_3\ \delta - R$, which must cover;

1. The cooling of all the air from t_o to t_1 or $WC_1\ (t_o - t_1)$ B. T. U.

2. The cooling of the whole air from t_1 to t_c or $WC_2\ (t_1 - t_c)$ B. T. U.

3. The condensation of w pounds of vapor superheated, $\lambda_1 - \lambda_2 + a$ thermal units above saturated condition at t_2, or $w\ [a+(\lambda_1 - \lambda_2)] + wr_3$ B. T. U.

Hence, $WC_3\ \delta - R = WC_1\ (t_o - t_1)] + WC_2\ (t_1 - t_c) + w\ (a + \lambda_1 - \lambda_2 + r_3)$

$$\frac{w}{W} = \frac{C_3\delta - C_1\ (t_o - t_1) - C_2\ (t_1 - t_c) - R}{a + \lambda_1 - \lambda_2 + r_3}$$

Let $p_1 = 220$, $p_o = 1$, $t_o = 32$, $t_1 = -200$.

Then $\delta = 0.27 \times 220 \left(\frac{461}{461-200}\right)^2 = 185°$ Fahr.

$$\frac{w}{W} = \frac{185\ C_3 - 232\ C_1 - 20\ C_2 - R}{a + \lambda_1 - \lambda_2 + r_3}$$

If $C_1 = 0.33$, $C_2 = 0.4$, $C_3 = 0.5$, $r_3 = 160$, and $a + \lambda_1 - \lambda_2 = 10$,

Then $\frac{w}{W} = \frac{7 - R}{170}$.

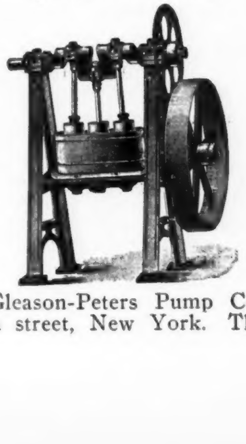
If $R = 3$, or about 3 per cent. of the cooling effect $WC_3\ \delta$, then $\frac{w}{W} = \frac{1}{42}$. This was the ratio of weight of liquid to weight of air compressed in the experiment to which Fig. 3 refers. The air to be liquefied was in this case confined in a separate vessel in the chamber E at about three atmospheres. The weight of air compressed per hour was about 85 pounds.

In another experiment about 65 pounds of air were compressed per hour to 190 atmospheres, and one-thirty-fifth of it liquefied and withdrawn directly from E. Liquefaction commenced in two hours, the weight of the coils being only about one-ninth of those used in the other experiment, so that less time had to be devoted to cooling the weight of the apparatus.

Analysis of the liquid product showed it to contain an excess of oxygen in both cases. Therefore the air does not remain a homogeneous substance, and this fact, together with the absence of any exact knowledge of the specific heats, and of the true value of the peculiar cooling influence δ, makes any attempt to calculate $\frac{w}{W}$ from thermodynamic laws a very rough approximation.

Air Jets.

A variety of air pumps that would come in exceedingly handy for experimental purposes and would answer where only a small quantity of air was needed are made



by the Gleason-Peters Pump Company, Houston street, New York. The illus-

tration shows an improved triple cylinder pump which can be operated by electric motor or from counter shaft. Requires but one-fifth h. p. at 75 revolutions and makes 150 lbs. pressure.

In December last a fire which destroyed the building occupied by Rogers, Peet & Company, corner Broadway and Warren streets, New York, disclosed the famous Beach Broadway Tunnel which was built thirty years ago for rapid transit purposes. It was proposed that compressed air should be used to drive cars through this tunnel. In the Spring of 1870 the tunnel was opened for inspection to the public and crowds of visitors enjoyed a walk through it—many people enjoyed rides through the tunnel in the car which was driven by pneumatic power. The remains of the car are still to be seen. It is elliptical in shape and practically filled the entire tunnel. In City Hall Park, where the tunnel terminates, an air well served as an outlet and inlet for air according as the car was driven by pressure of air on its end down the tunnel from the huge blower or driven back to the place of starting by the suction of air in a reversed direction. Horace Greeley and other distinguished persons took rides in this car.

PNEUMATIC CAR IN THE BROADWAY TUNNEL.

With the present form of high pressure liquefying apparatus it requires approximately twenty (20) h. p. to produce one gallon of liquid air.

The relative volume of free air to liquid is nearly 800 to 1.

J. G. Brill & Company, of Philadelphia, Pa., are using compressed air to a considerable extent in their works and for a variety of purposes. One large two-stage compressor with a capacity of 550 ft. of free air per minute is employed. A great many hoists are used in the machine shop both of the vertical and horizontal types. They also use a number of chipping hammers and reamers and have quite an interesting sand blast for removing the rust and scale from the exposed iron work, which goes into passenger coaches. Compressed air in a deep artesian well lifts the water about 300 ft.

One of the most important and interesting events in pneumatic tool matters of late, was the purchase on the 6th day of April, by the National Pneumatic Tool Company, of Philadelphia, Penn., from the American Pneumatic Tool Company, of New York, of the sole and exclusive right to manufacture pneumatic chipping, calking and riveting hammers under all patents owned by the latter company, who were the first concern to place this class of tool on the market. The American Pneumatic Tool Company have brought a number of suits for in-

fringement of their patents on both valve and valveless hammers, and the United States Court of Appeals for New York has unanimously decided in their favor. It is their intention, so it is stated, to bring suit for infringement against all users of hammers not manufactured by the National Pneumatic Tool Company. This purchase, we understand, was effected by the National Pneumatic Tool Company with the idea of saving and preventing their customers from annoying litigation and consequent excessive damages for infringement.

Mr. John S. Thurman, formerly mechanical engineer of the Missouri & Pacific railway system, has resigned that position to promote a pneumatic carpet renovator which he has invented. Mr. Thurman invented and designed many of the standard air appliances now in common use in various railway shops.

The carpet renovator spoken of will consist of a suitable wagon, a gas engine, an air compressor, storage reservoir and a reel of hose. Wagon to be self-propelling so that it can be run any distance and be placed in any position. This will make the plant convenient for residences and other buildings. The hose is run into the house and on it is attached a dust collector and the carpets are cleaned at your residence without clouds of dust or other disagreeable features.

It is estimated that this plant will clean from five to six nine-room houses in one day. It should be very much cheaper than the usual method of cleaning carpets by machinery, because there is no expensive plant to keep going and there is a saving of cartage and other incidentals.

It will require the services of an engineer to run a vehicle and look after the machinery when it is stationary and compressing air. Services of one expert will be required to clean the fabric on the inside of the dwellings. It is estimated that a 9-room house can be cleaned thoroughly at the cost of about $1.75, and that without removing the carpet from the floor. The dust collector cleans the carpet so thoroughly that not a particle of dust is left between it and the floor. This process is entirely feasible, as will be readily understood by all those who are familiar with the action of air. A city of the size of St. Louis would require from 18 to 25 wagons equipped with the apparatus.

The Chicago Pneumatic Tool Company announce some valuable acquisitions to their working force in securing the services of Messrs. W. P. Pressinger and J. M. Towle.

"Mr. Pressinger is well known to users of compressed air everywhere, through his long connection with the Clayton Compressor Works, and he now leaves them to work with our New York office.

Mr. Towle, who will open an office for us in Boston, has been for the past ten or twelve years engaged in the manufacture and sale of pneumatic tools, and is an expert in that line, and well known throughout the East where his work has principally been done."

"Liquid Air and the Liquefaction of Gases" is the name of Prof. T. O'Conor Sloane's new book, published by Norman W. Henley & Co., 132 Nassau St., New York. This branch of science is the most absorbing subject of the present day. Up to now it is almost chiefly confined to experiments—Cailletet, Dufour, Tripler and Dewar are among its chief experimenters—and just at the present time a large plant is being installed in New York for manufacturing liquid air in large quantities. With the active work of experimenting and the more practical work of manufacturing comes a desire for information relative to the production and use of this truly wonderful power. As the author says, "If liquid air could only be produced cheaply enough it would represent an ideal substance for the production of energy." Prof. Sloane has gathered about all that there is known of this subject and put it in such shape as to make his book very valuable, up to the point that the development of liquid air has reached. The book contains 357 pages in convenient form. It would be quite impracticable to give a synopsis of the work here further than to say that by means of illustrations and tables the problem of liquid air takes an organized form. Besides the pictures of mechanical devices used in the production of air and the experiments with it, the book has good portraits of the leading exponents of this question. Sketches of their lives lead us up to their work in liquid air. Considering the work of compilation the price, $2.50, is moderate.

In an article on the use of compressed air in mines in "Mines and Minerals," Professor Robert Peele says:

"The exhaust from machines driven by compressed air, on the other hand, is not only not a detriment, but is of positive benefit. Large volumes of fresh air are discharged in the working places, just where ventilation is most needed. When exhausted, the air is cool as well as pure, comparatively extremely dry. The humidity of the intake air at the compressor may be high, but as the air cools after compression a large part of its moisture is deposited in the receiver and piping, so that the percentage of moisture in the exhausted air—when it has expanded again and resumed its original volume—is small. This feature is made of practical utility by the miner for cleaning out drill holes preparatory to charging. A piece of gas pipe is attached to the end of the air hose, inserted in the hole, and on turning on the air the sludge is blown out and the hole quickly and thoroughly dried.

PATENTS GRANTED MARCH, 1899.

Specially prepared for COMPRESSED AIR from the Patent Office files by Grafton L. McGill, Washington, D. C.

621,779.—Air Brake. Ansley & Topham, Atlanta, Ga.

This invention consists of a brake-cylinder and an auxiliary reservoir, the latter being connected by passageways to the valve-chamber. The piston is inclosed within and carried by a sliding casing, whereby, when in position of brakes applied, only the auxiliary reservoir is charged and not the brake-cylinder.

621,536.—Apparatus for Liquefying Air. Ostergren & Burger, New York, assignors to General Liquid Air and Refrigerating Co., New Jersey.

The apparatus consists of a closed condensing cylinder having two spiral partitions formed of metallic sheets arranged therein and constituting narrow channels respectively for the ingoing cold and compressed air and the outgoing expanded air. Supply and discharge pipes are provided for the compressed and expanded air channels, respectively, while a central pipe is provided with ports to permit the compressed air to pass from the ingoing to the outgoing channel. The liquid air is drawn from a separate port in the lower portion of the central pipe.

621,537.—Apparatus for Liquefying Gas. Ostergren & Burger, New York, assignors to General Liquid Air and Refrigerating Co., New Jersey.

In this condenser the two series of spiral concentric channels are arranged one above the other in the same vertical plane, one being adapted to conduct the ingoing current of aeriform fluid, and the other the outgoing current of expanded fluid. A third spiral channel is arranged intermediate the coils of the first mentioned channels to carry outgoing currents of further expanded fluid, while a series of connected expansion chambers are connected to said channels and adapted to contain various pressures.

620,822.—Air Compressor. H. E. Anderson, Cheboygan, Mich.

A frame, arranged to revolve about a shaft, is provided with guideways extending about the shaft in the direction of chords of a circle. Weights are mounted in the guideways to have a limited reciprocating motion, while an air-compressor cylinder and pistons are attached to each of such weights. Water chambers surround the cylinders for the purpose of cooling them, and the cylinders are connected to an axial discharge pipe located in the shaft, the latter being formed with two central partitions.

620,963.—Aerating Water in Bottles. H. V. R. Reed, London, England.

The stopper is provided with means for holding a capsule and releasing the gas therein. An external safety air chamber is secured to the stopper and has communication with the interior of the bottle, and an ejecting tube, also secured to the stopper, communicates with the capsule-holder and forms a passageway for the gas from the capsule. A perforated circulation chamber surrounds the ejecting tube and receives the gas therefrom.

621,841.—Air Valve. J. H. K. McCollum, Toronto, Canada.

The valve has a hollow stem formed with a head provided with side notches for the passage of air outside of the stem, the latter forming a valve-seat at its upper end. The casing, which has a reduced lower portion, is provided with an elastic tubular covering, extending below the said lower portion and below the valve stem.

620,830.—Air Supplying Apparatus. F. A. Baynes, Buffalo, N. Y.

This invention relates to an apparatus for supplying air to a carbureter in which artificial gas produced by forcing air through a body of hydrocarbon oil. An upwardly opening water chamber is adapted to receive a vertically-movable dome, the latter having its lower open end in such chamber. An air-supply pipe opens into the dome above the water line, such pipe having its outlet provided with a check valve, while air chambers are arranged on the valve and immersed in the water of the chamber. Air is delivered to the dome or air holder by means of mechanism comprising two vertical cylinders arranged side by side and each partly filled with water. The two connected plungers, which act in opposite directions in the two cylinders, are each provided with a water-chamber and discharge pipes, together with a deflector plate adapted to direct the supply of water into the cylinders, the water supply being received and delivered by an oscillating siphon cup located above the two cylinders.

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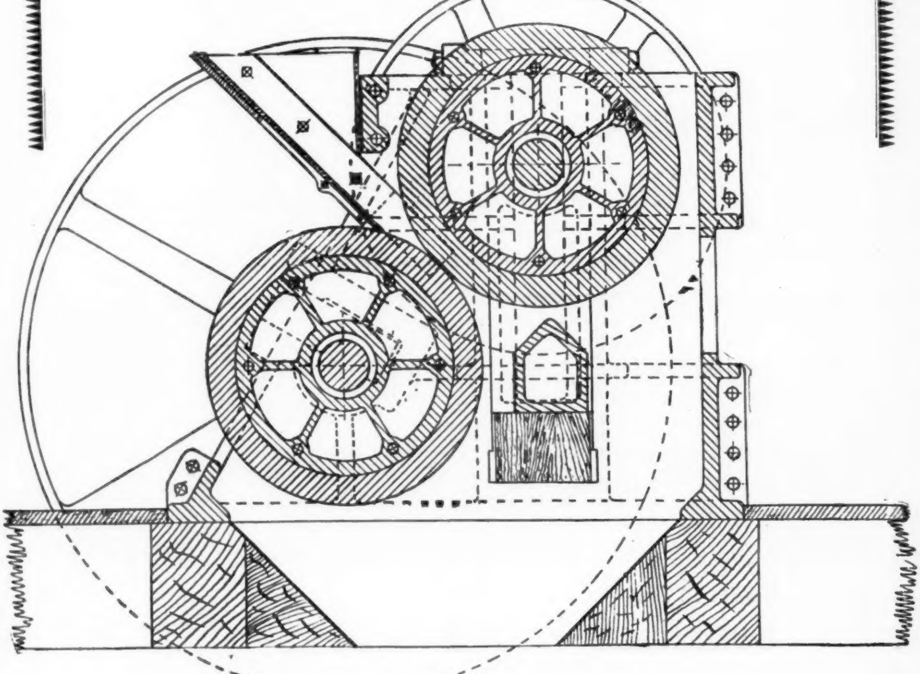

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